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BY

CHESTER SCHENCK

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CHESTER SCHENCK

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DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

Morgan Brooks
Instructor in Charge

APPROVED: Ernst Berg

HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING.

PRIVATE BRANCH TELEPHONE EXCHANGES.

TABLE OF CONTENTS.

Page

I Introduction. 1

II Some Methods of Increasing Telephone Equipment. 2

III Reasons for Using Private Branch Exchanges. 5

IV Where Private Branch Exchanges are Commonly Used. 7

V Equipment. 8

- A. Preliminary Statement. 8
- B. Manual Equipment. 9
  - 1. Characteristics of the Equipment. 9
  - 2. Characteristics of the Operation. 10
  - 3. Special Functions of the Operator. 10
  - 4. Hotel Manual Private Branch Exchanges. 12
- C. Automatic Equipment. 13
  - 1. Characteristics of the Equipment. 13
  - 2. Description of Automatic Equipment. 16
    - a. General Description. 16
    - b. Automatic Private Branch Exchange Equipment. 19

VI Cost and Maintenance. 25

VII Battery Supply and Supervision. 29

VIII Conclusion. 34

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Gerald Deakin.

PRIVATE BRANCH TELEPHONE EXCHANGE.

I.

INTRODUCTION.

The telephone in its early forms was mechanically crude and imperfect, yet even then it was able to demonstrate the possibilities of great economy to be obtained by the transmission of human speech from one point to another. Later development had taken place along lines which have tended toward more perfect transmission of the voice sounds, greater convenience, greater speed in completing calls, and less rental to be paid by the subscriber.

One of the most noticable features in connection with furthering the value of the telephone as a convenience has been the use of more telephones. The operating companies have always endeavored to increase the number of their subscribers; both for the direct revenue to be obtained, and because the value of their service is increased by having a large list of subscribers. During the last few years another factor involving the use of additional telephones has become of importance.

The patrons of the telephone exchanges are caring for their own convenience by installing several instruments in a given establishment instead of attempting to get along with one. Even in private residences it has become the practice to have an extension set on each floor rather than to answer a telephone call on another floor which must be reached by a stairway. Some establishments, such as business houses, are so complicated and

extensive in their organization that it becomes desirable to install a considerable number of telephones, each having a connection with a switchboard equipped in a way sinilar to some form of central office equipment.

A system so installed is in effect a small exchange, and may, or may not, have connection with an outside central office. When it does have such a connection, it is a branch exchange, located on private property for the interests of the parties for whose use it was installed. The name "Private Branch Exchange" has, therefore, been applied to this form of installation. Incidently, it may be mentioned that the recognized abbreviation of "Private Branch Exchange" is "P. B. X.", which owing to its convenience, will be used to some extent in the following consideration of the topic.

The purpose of this paper is to consider in reference to the private branch exchange; some of the reasons for its use, the advantages which it may provide, its adaptability to various classes of duty, the types of equipment used, and, to some extent, the cost and maintenance of equipment.

II.

SOME METHODS OF INCREASING TELEPHONE EQUIPMENT.

In the normal growth of an establishment where more building are being built, more office and factory room added, it becomes desirable to provide more telephones. The least equipment possible at a subscriber's premises is one complete instrument, and for small establishments it is customary to

take care of a limited amount of increase by adding extension sets, so that several of these telephones are connected together on the same line.

This arrangement allows two or more persons to come onrthe line to make a call at the same time, but usually, where the telephones of the line are all on the same premises, little difficulty arises from that cause. It is desirable at times for these different parties to be able to call each other without disturbing the operator. By an additional arrangement this result can be accomplished. A cable containing one pair of wires for each instrument connected, and in addition four to six wires for local talking battery, signal battery, etc., must be run from instrument to instrument on the line. A series of push buttons thus makes the different circuits, and gives the necessary signals.

There are several objections to arranging telephones intthis way. The trouble due to interference of more than one party trying to call is never completely eliminated. The cable is expensive, both in first cost and installation. Also, the connections are intricate and considerable difficulty is experienced in adding a new station or re-locating an old one. For these reasons, this type of connections is only used for a limited number of stations, usually five or ten, and even then only for establishments having a definate number of offices not likely to change, such as banking houses.

Increase of telephones by extension sets may not be

satisfactory. As an alternative, each telephone installed may be provided with a direct line to the central office. The rental for direct lines will cause the firm's telephone bill to vary in proportion to the number of direct lines used. A call from one of the telephones to another will require two cable pairs to the central office. Each line added requires a new cable pair of its own.

In arranging for this form of service the central office must install a cable to the establishment of sufficient size to take care of all future increase, so as to have pairs always available, or find itself obliged to install more cable at some later date. The former plan involves investment in cable which may be idle for an indefinate length of time while the cable is only partly in use. The cost per working line for maintenance may become excessive if the cable has many pairs idle.

A private branch exchange to care for the telephone requirements of some particular establishment is usually located near all the stations. Short local lines connect the telephones to the P. B. X. board and a few trunk lines provide for outgoing and incoming calls to and from the central office. Local calls each require two pairs to the P. B. X. board, and outgoing calls one pair to the P. B. X. and one trunk to the central office. The length of cable pair to handle a local call is very small as compared with the arrangement previously described. A telephone added only requires the short line to the P. B. X.

III.

REASONS FOR USING PRIVATE BRANCH EXCHANGES.

Community of interests is one of the chief reasons for the use of private branch exchanges, resulting in a large number of calls made locally between stations. These calls through a P. B. X., as has been pointed out, involve a comparatively s small investment and are for that reason handled cheaply. The increase of outgoing and incoming business for each addition of a telephone on the P. B. X. is much smaller than the corresponding increase of local calls.

It is the custom with most central offices to make either a low rental for each telephone on the private branch exchange, or to base the rental on the number of trumks required to handle the central office calls. The company using the private branch exchange is in either case enabled to have as many instruments as may be desirable for convenience without the rental becoming prohibitive. It is quite common for a firm to own its private branch exchange equipment and only pay for trunk service. The company is in this case able to make a very liberal provision of telephone instruments for its employees and not increase its rental in the least.

An incidental convenience may be noted in some private branch exchanges in that it is simpler to obtain the local call than other calls. The expense of handling may be somewhat lessened in these cases because the larger number of calls are handled in the simpler way.

Previous mention was made that the upkeep of a cable for supplying direct line service might become excessive when

reckoned on the basis of working lines. A trunk cable to a private branch exchange deserves a different consideration. The number of central office calls generally increases more slowly than the number of local calls, and at a more definite rate of increase. A trunk line can be depended on to care for about a certain number of calls per hour, dependent on the method of operation and the type of equipment. The number of trunks installed to connect with a private branch exchange usually depends on how many the user is willing to pay for, but the number required can always be determined, and be kept a minimum depending on the number of calls passing.

The central office is, under the trunk system, only obliged to install as many lines to the private branch exchange as are absolutely necessary, and very little provision need be made for the increase of trunks which may never be required. Very few idle cable pairs are provided, and the actual cost and maintenance of the cable is properly chargable to working pairs. The total cost and maintenance of trunks to the private branch exchange is less because the number of pairs is less.

It is not the intention in this paper to attempt to prove that the extra investment for the private branch equipment, where it is owned by the telephone company, is justified by the saving in trunk cable cost and maintenance. Experience has shown, however, that so far as such cost and investment considerations are concerned in central office practice, it becomes more profitable to install a small exchange to care

for local business of isolated groups of subscribers when the distance to the group is greater than a certain limit dependent on local conditions.

This exchange must be served by trunks to the main exchange and, with some forms of equipment, trunking through the extra exchange may tend toward less convenience and slower speed in calling. In some cases this question of convenience and speed is of such movement as to prevent installing the small exchange.

When considering private branch exchange equipment the saving in cable cost and maintenance might not be sufficient reason for its use, but considerations of convenience to the users nearly always weigh in favor of the P. B. X. With them the bulk of the calling is so much facilitated that slight differences in the trunk service may be over-looked.

The reasons for using a private a private branch exchange, then, may involve any one or all of the three considerations mentioned at the start - greater convenience, higher speed, or less rental for a given number of connected instruments.

IV.

WHERE PRIVATE BRANCH EXCHANGES ARE COMMONLY USED.

Private branch exchanges are commonly used in a class of establishments which are of comparatively few kinds. They may be grouped roughly as hotels and apartment houses, schools and colleges, business houses and commercial establish-

ments, including factories. In short any group of persons may have its telephone service supplied through a private branch exchange, but it is customary to install a P. B. X. only where the group of persons has interests in common making it desirable for them to have rapid intercommunication between stations.

V.

EQUIPMENT.

A. Preliminary Statement.

Telephone equipment has been developed along two widely different plans; viz. the manual system where the connections for a conversation are made by an operator instructed verbally by the calling party, and the automatic system, where the party originating a call establishes his own connections by operating a dial on the instrument.

Private branch exchange operation, especially where the user installs and owns his own apparatus, brings about four possible combinations. The P. B. X. may be either manual or automatic, and the office to which it connects may be either of the two forms. It may be said that, while each combination presents a different problem in arranging the trunk apparatus, no difficulties are presented which can not be surmounted. The circuits are readily arranged in every case so as to handle calls freely in each direction.

The plan of this paper is to take up as fully as may seem desirable the characteristics of the two forms of P. B. X. equipment, and to point out the advantages of each. The in-

tention is to discuss the detail of the automatic apparatus more fully then the manual.

B. Manual Equipment.

1. Characteristics of the Equipment.

Lines from the subscribers sets of a manual private branch exchange terminate at drops and jacks, or lights and jacks, the same as in the boards used in central offices. Connections are made by cords, and supervised by lights in the cord circuit in a manner similar to central office operation. The system for signalling the operator may use either magnetos or preferably a common battery supply.

All local calls are made by a simple cord connection. Outgoing calls are given to the private branch exchange operator who makes the call through the central office in the same way as any other central office subscriber. Simularly incoming calls are answered by the operator who calls the party wanted on the proper P. B. X. line. The supervisory lights indicate when a conversation is finished and the cords are taken down.

Manual private branch exchange boards are usually located in some office or assembly room where it is not desirable for repair men to go during business hours, because of disturbing both the workers and the operator. The location is sometimes made in a conspicuous place for advertising purposes. There are usually difficulties in repairing manual P. B. X. boards for these reasons.

2. Characteristics of the Operation.

A telephone operator is found to work at her highest efficiency when she is handling the maximum number of calls per hour of which she is capable. In private branch exchange operation, it seldom occurs that the operators can operate at anything approaching their maximum rate on account of lack of calls. The result is, as has been found, that calls which involved a connection through a manual private branch exchange are slower for two reasons. First the time for the P. B. X. operator to answer and receive instructions must be considered as additional time required over an ordinary central office call, and then the fact that she habitually works at a slower rate than the regular exchange operator is also involved. It had been observed that both the P. B. X. and central office operators are slower in disconnecting the cords after a conversation is completed.

These disadvantages of the service in times of moderate calling are intensified during the times of day when the calling is highest. When calls are infrequent the time of putting each call through is subject to extra delay because the operator instead of merely continuing the motion of completing one call into making another must start the hand from rest to care for the isolated calls.

3. Special Functions of the Operator.

Mention was made previously that the incoming calls to a manual private branch exchange were answered by the operator and completed after receiving the necessary instructions. This

seemingly simple part of her duties brings her in such close contact with the incoming traffic as to make the handling of these calls one of her most important functions. Persons who are acquainted with the private branch exchange situation, of course require no special consideration, but frequently calls come to the operator from persons who have business of some form or other, but do not know just whom should be called in reference to the matter. It is desirable for the private branch exchange operator to be able to give the person calling, connection with the proper line with the least delay possible. It has been recognized by some firms, but unfortunately not by all, that to do this satisfactorily, the operator must possess qualities of tact and judgement, and must be furnished with as full and complete information as to the organization and arrangement of the business as possible. The opportunity for smoothing out difficulties can very easily result in cinsiderable saving of time and annoyance to all parties concerned. It may become quite a valuable asset for firms having more or less incoming calls, if the operators maintain an attitude such that customers, not sure of the proper placing of their calls, can always rely on receiving courteous and careful attention when they depend on the operators to direct their calls for them. Occasionally only one number is advertised for a private branch exchange, so that all calls must be distributed by the operator, and no outside party calling be allowed to assume that he knows to whom he wishes to speak or with which department he has business. Sometime may be saved from waste by misdirected calls in

this way.

In some private branch exchanges the custom is to give the number desired to the operator, then hang up the receiver until the operator obtains the party and rings back on the line. The person called is in this case told to "wait a moment", and as sometimes the calling party is unable to answer instantly when rung back, it throws the burden of waiting on the called party. This is bad practice, and no users of private branch exchange service should have the discourtesy to assume that their own time is any more valuable than that of the called party, or that the called party is any more disposed to wait. The practice should be discouraged.

4. Hotel Manual Private Branch Exchange.

Private branch exchange development is a matter of thelast few years, but one particular class of users has thoroughly awakened to the advantages offered. All newly built hotels have the telephone switchboard installed as a matter of course, and practically all older hotels have, where the construction of the building permits. The nature of hotel service has been such that equipment has been nearly always manually operated in connection with an automatic city exchange. The calls which are handled are largely calls from the occupants of the rooms to the operator or vice versa. They are frequent and of little importance in themselves, yet must be handled, and do add to the convenience and comfort of the guests. These calls were formerly handled by bell boys who actually went to the rooms when called

by a bell, so that the telephone method is more rapid and cheaper for the hotel management. The operator is sometimes able to give assistance to a guest who is hurried or unacquainted with the city by ordering cabs, arranging for baggage transportation, for sleeping car accomodations etc.

From these considerations it will be seen that the advantages of manual private branch exchange service are largely dependent on using the intellegence of the operator in as many ways as possible rather than to hold her to the machine-like operating methods of the central office girl.

C. Automatic Equipment.

1. Characteristics of the Equipment.

Automatic telephone instruments which are to be used with automatic private branch equipment are not different in any way from those connected to the main automatic exchange. The latest type requires but two wires between the instrument and switchboard, and no ground connection is used. Each one of these lines is connected to a certain unit of apparatus which may or may not be capable of selecting numbers. If this unit be of the latter type, or what is known as the Keith type line switch, the removal of the receiver from the hook completes a battery connection which instantaneously connects the line through trunks to a switch or selector which is capable of receiving impulses and calling numbers. With the receiver off, the battery connection is complete, and calls are made by opening this circuit the required number of times for each digit of the number called

by rotating the calling dial. An intermittent ringing current signals the party called when the dial has been rotated for the last digit. If the line called is busy, a characteristic intermittent buzzing noise is heard in the receiver. All apparatus used in making a call is restored to its normal position by returning the receiver to its hook.

Making a regular city call on any automatic installation requires the calling of a certain number of digits. Out going calls from a private branch exchange to city stations require a single digit to be prefixed to the regular number, and if the call goes into another automatic private branch exchange two more digits must be added at the end. Three extra digits is the most and calling these requires three extra motions and perhaps three seconds of time. This slight difference is the only one which exists between automatic private branch exchange calling and automatic main line calling.

There is no added delay while instructing extra operators nor any extra time required because of slow private branch exchange operators. The calls are made automatically exactly the same way and in the same time whether traffic is heavy or light or whether the call is an isolated call or not. Local calls are made on two or three numbers and these are accomplished in so short a space of time that it is quite common to have the party called answer his telephone within the same length of time required for the manual operator to answer and receive the proper instructions.

Another very important point for consideration is that disconnections are made instantaneously by the one calling, and owing to the construction of the apparatus it is possible for a person making several calls in succession to hold the same trunk thereby and have absolutely no delay. The time and annoyance saved is frequently quite appreciable.

The assistance of the operator is eliminated from the local calls, outgoing calls, and a large percent of the incoming calls. The discussion of the value of personal attention to indefinite incoming calls given previously applies, however, just as forcibly as before. The difference is merely in the method of handling the calls, They are in this case the only duty the operator has in connection with the exchange. It is seldom that enough incoming calls must be answered to keep an operator busy, so the custom is to have some one in the office answer the calls in addition to her other duties. There may be a special number listed in the directory of the city exchange indicating that this particular telephone is to be called for information concerning the private branch exchange numbers. With some arrangements the clerk will complete these calls for the parties calling.

In some cases where all questions can be answered by giving the proper number to call, it may be desirable to have inquiries for information answered by the regular exchange information operators who are supplied for this purpose with the neccessary lists. This method is found to add very little burden

to the regular duties of the operators, and for certain classes of establishments, as apartment houses, is found to be the best method of dealing with the situation.

2. Description of Automatic Equipment.

a. General Description.

The equipment for automatic private branch exchanges follows very closely the same general type of the central office equipment. With automatic equipment each line connects to a Keith type line switch. These primary line switches consist chiefly of an electromagnet which when energized by a current through the calling telephone, forcibly thrusts an insulated metal plunger into a bank of ten contracts. By the particular contact secured the calling line is connected through a trunk to a secondary line switch of the same type, which in turn connects the line in a similar way through a trunk to the first selector. The line switches are in groups of one hundred with usually ten of the trunks to secondary line switches but with a possibility of increasing them to forty for the hundred.

Each line switch of the hundred has its plunger held opposite one trunk contact on the bank by suitable plunger guides. When one plunger goes in on a contact all others are thereby rotated to another contact. The rotation of the plunger guides preselects the trunk. This feature enables several line switches to be operated simultaneously by removing the receiver of the telephone before the calling dial has been turned.

The primary line switch has thus a choice of ten trunks and each of these trunks leads to a secondary line switch capable of selecting any one of ten first selectors. Any line is in this way, because of the pre-selecting feature connected through trunks to one of a group of one hundred first selectors.

The piece of apparatus called a first selector is typical of the number selecting devices. It consists of a vertical shaft, carrying flexible metal wipers, so arranged as to be capable of both vertical and rotary motion in definite steps when actuated by successive impulses of current from the calling device. The shaft is capable of placing the wipers opposite any one of ten different levels of contacts on the switch bank by the vertical motion, on receiving the proper number of impluses, and of rotating the wipers to any one of ten contacts on each semi-circular level usually by current impulses from a locally interrupted circuit on the switch itself. The rotary motion on selectors usually is set in motion by a device consisting of relays acting at different speeds. The impulses of current to controll the vertical motion of the shaft pass through two relays, a rapidly acting relay and a slow acting relay. When the receiver of the calling telephone is removed the circuit is made so that both of these relays are energized. The battery connection is broken a certain number of times to step the shaft of the selector up the same number of levels. The rapidily moving relay must respomd to each of these impulses in order to controll the vertical motor-magnet

circuits. The slow acting relay does not have time to denergize during the recurrance of rapidly repeated current impulses. When a short delay occurs as when the calling party is rotating the dial preparatory for its calling another digit, the slow acting relay has time to de-energize, and by so doing the circuits are changed so that the rotary motor magnet rotates the shaft with its wipers to the proper contact. The rotary motor magnet on selectors is controlled by a feeler wiper, or private wiper, rotating over bank contacts similar to the regular line banks. When a trunk is in use a guarding potential is extended to all corresponding private contacts on selector banks which have access to that particular trunk. This guarding potential on a busy private bank contact causes the rotary motor magnet of a selector to give one more rotary thrust or step. When a contact is reached, by the selector hunting for an idle trunk, not guarded by this potential the extra impulse is not received, and the selector remains on that contact. The circuits of the selector change simultaneously so as to cut out of circuit all magnets of switch and extend the calling line through the trunk to the next wsitch. The selector on obtaining a trunk immediately extends its own guarding potential to all the private contacts of that trunk.

The remainder of the connection takes place by means of second selectors, sometimes third or fourth selectors, all working on the same principle as the first selectors, and connectors which complete the connection.

A connector operates slightly differently from the selector described. It always is actuated by the last two digits of the number called, and makes the final selection of the called line out of its hundred group. The next to last digit steps the shaft up as it does a selector, but the rotary motion is controlled by the last digit called. The level called selects the ten out of the hundred, and the last rotary motion selects the particular digit out of the ten on that level. The connectors ring the party intermittently, and finally supply talking battery.

The actual circuits for these switches are complicated and beyond the province of this discussion. A somewhat fuller description of the action of the switches in calling is presented in an article by W. Lee Campbell on "Modern Automatic Telephone Apparatus" in the Proceedings of the American Institute of Electrical Engineers for 1910, Page 55.

(b). Automatic Private Branch Exchange Equipment.

When private branch exchanges were first attempted on the new two wire automatic system they were virtually the same as the small unattended sub-offices which are much in use. The equipment consisted of the primary line switches which trunked to primary line switches at the nearest central office, and through secondary line switches to first selectors. A local call required two cable pairs to the central office as was required in one form of manual arrangement previously described. The difference is that these pairs are trunks available to any one of the line switches, but not permanently connected to any one line. The advantages of short local lines and lessened cable cost are realiz-

ed to a considerable estent. The equipment of this form for incoming calls consists of connectors on the private branch exchange board. Local calls require the full number of digits with one or two extra. Where the local calls are not a large percentage of the total calls it is quite common to install apparatus of this form still.

Frequency of local calls demanded for rapid operation and small investment a simple method of making these connections. The rotary, or slip, connector has been the solution of the problem. It was originally developed for trunk service for business firms so that by assigning them several numbers in succession on the same level of the connector they might have the benefit of a number of trunks. All calls normally come to the first of the series which is the only number listed, and if it is busy the connector automatically passes on to the next contact, or to the first of the contacts not busy, or gives the busy signal if all are busy. For other numbers the action of the connector is perfectly normal.

The application of the slip connector to the private branch exchange eliminated the use of trunk cable pairs for local calls and cut the number of digits required to two. One level of the connector bank is reserved for outgoing trunks and on this level the slip or rotary feature of the connector is utilized to rotate the wipers over busy trunk contacts till an idle one is found. On the other levels the action is as an ordinary connector and the multiple of private branch exchange numbers is placed on these levels. A local call of two numbers steps the

connector up and rotates it to the contact called. The first number of out going calls is peculiar to the private branch exchange, and lifts the connector wipers to the trunk level. The wipers then rotate to an idle trunk, and the remaining numbers operate switches in central offices which may be miles away.

A repeater may be used on each outgoing trunk. The function of a repeater is to relay the calling impulses from the apparatus using the private branch exchange battery to the apparatus in the central office using the central office battery.

From this method of operation it is evident that the trunks from the line switch banks are in this case connected directly to the slip connectors. The line switch of the calling line plunging in on a contact, is connected to a rotary connector which if it calls an outgoing trunk causes a primary line switch and a secondary line switch in the central office to plunge in and obtain a first selector in the usual way.

Line switch boards are usually built to contain one hundred lines each, but are in such form that the equipment may be mounted in groups of twenty-five and fifty as well. The different sizes are provided with different numbers of rotary connectors as may be required.

The different boards may also be equipped with recorders for counting and recording all completed calls. Sometimes it is desirable to know whether the equipment provided is sufficient to care for the calling. For this purpose devices are sometimes installed to count the number of attempts made to call when all the outgoing trunks were busy, attempts to make local

calls when all the rotary connectors were busy, and attempts to call in when all the incoming trunks were busy. Incoming calls may be arranged either to have access to the rotary connectors for calling the final figures or may have connectors for each trunk. Usually the former is practiced.

The automatic private branch exchange does not need to be located so that an operator can have access to its parts for making calls. It is commonly built in a form readily accessible for making repairs, and located anywhere that may be convenient. The location should be reasonably dry and not subject to too rapid fluctuations of temperature.

An article in the April 1912 number of the Proceedings of the American Institute of Electrical Engineers on "Automatic Private Branch Exchange Development in San Francisco" by Mr. Gerald Deakin, has just appeared and his discussion takes up the detail of the installation and maintenance of the two types of line switch unit described quite completely.

A type of private branch exchange equipment has been developed in connection with the Chicago exchanges of the Illinois Tunnel Company. This type goes back to the early form of automatic equipment where each line had a first selector for its own particular use. These boards are made in a size which accomodates a maximum of thirty lines. Each line has a first selector whose bank only has two levels of contacts. When an outgoing call is made the number prefixed is two and the top level of contacts used contains the multiple of the outgoing trunks. For local calls the first level contains the multiple of trunks to the local connectors of which seven are all that it is deemed necessary to pro-

vide. The connectors are built with only three levels on the banks for the thirty lines and do not have the rotary feature.

The selectors are mounted on three shelves of ten each with the fourth shelf for the connectors and the repeaters for the outgoing trunks. At one end of the case which is finished in mahogany and glass are compartments for two sets, each consisting of a ringing pole changer and interrupter and the busy signal producer. The complete set is built in this form because it is cheaper than the line switch type up to a limit of thirty lines. Three digits must be used for local calls.

Aside from this particular form of board the usual type of switch always has ten levels on the banks, and in small exchanges part of these levels are never filled. It has never been feasible to build switches of fewer levels because the ultimate size of an exchange is always a matter of doubt. In this case the limit was fixed arbitrarily.

The previous description of private branch exchanges has been principally confined to small sizes. As in manual boards of large size the equipment loses its more special adaptations for exchanges of larger capacity. Formerly with older types of equipment private branch exchanges were installed of comparatively large size and each line provided with a first selector as was the case in the exchange of the University of Illinois. However the greater economy of the line switch type and lesser first cost have caused the partial abandonment of this type. Private branch exchanges of large capacity are built up of Keith type units of one hundred lines each to make any size needed. Usually the one

thousand line plan is followed and each one hundred lines may have ten first selectors and ten connectors. Three digits are used for a number. It is possible for ten outgoing and ten incoming calls per hundred lines to exist at a time which is ample provision. A smaller number of first selectors and connectors can be installed at first if the calling is light. There is,of course, no limit to the size of private branch exchange which can be equipped.

VI. COST AND MAINTENANCE.

The following data was obtained on the cost of automatic private branch exchange equipment for the purpose of making comparisons with the manual apparatus.

The prices include complete equipment.

25 lines	$40.00 per line
50 lines	$30.00 per line
75 lines	$27.00 per line
100 lines	$25.31 per line

They are based on the assumption that either direct current of 110 volts or 220 volts are available for charging the storage batteries, and include a power panel for this purpose. If alternating current must be used a mercury or rectifier is necessary and the additional cost would be about $146.

As a matter of comparison a manual board to care for 50 lines would cost in the neighborhood of $12. per line or a total of $600. as against $1500. for the automatic, both including switch board and telephones. The first cost for the automatic is greater by $900.

If now the fixed charges, represented by interest and depreciation, are estimated at say 12% for each board, the exact percentage varying for different conditions, the yearly charges for the manual board are $72. against $180. for the automatic.

First cost and fixed charges are nearly always higher for the automatic systems and this is a typical result.

The apparatus is somewhat different and the extra first cost is

due to greater amount of material and labor required in building.

Considerations of the economy of the two types must always include operation and maintenance. The instruments used for manual and automatic private branch exchange service differ only in the calling device which is peculiar to the automatic telephone. The working parts of the device are concealed within the set and are not liable to be tampered with, so that the maintenance cost of the two types of instruments is the same.

The manual board requires frequent repairs in the form of cords, plugs, jacks, lamps etc., parts which are worn out or damaged in actual service.

The automatic switching apparatus can be maintained by the regular electrician or engineer on the premises where the private branch exchange is being installed, and he can keep the apparatus in perfect working condition by giving it from 15 to 30 minutes attention each day, simply making minor adjustments, seeing that screws are properly set, and attending to charging the battery. The actual time spent on small exchanges will be so small as to be difficult to calculate its actual cost when it is done in that way. For this consideration it will be unnecessary to include the repairs and maintenance just mentioned on either type.

The manual exchange requires for its operation some one to be at the board during working hours to make the connections. Operators wages vary somewhat but in large cities are something like $50. per month or $600. per year. The yearly charges of the manual system must include the ooperators salary or a total of $672. The difference between the yearly cost of $672. for the

manual and $180. for the automatic is $492. This is another typical result of such comparisons since the operators hire must always be considered. Increase of lines on the automatic system takes place at a decreasing cost per line with a correspondingly less increase of fixed charges. Manual boards must employ more operators when the capacity is sufficiently increased, so that the operating cost always brings the yearly expense above that of the automatic system. In the case under consideration the saving in the yearly expense of the automatic over the manual is over half the increase of investment apparatus originally. This means that in two years the extra investment is returned to the owners, and that through the succeeding years the yearly saving between the two is clear profit.

As some automatic calls are handled by an operator it may be well to consider the effect on the yearly charges. For small exchange the calls are few, and are cared for by some one in the office who received no special salary for doing so. It is conceivable of course that an automatic private branch exchange might become so large as to employ an operator who would devote her entire time to the calls. The corresponding manual P.B.X. would presumably employ several operators. From the results of the cost considerations previously deduced it was found that a considerable part of all the operators wages, or even the wages of one operator, were saved by the use of automatic equipment. The saving in the large P.B.X. would be so great that even if one operator must be employed it only adds a comparatively small amount to the yearly costs of the automatic system and still leaves the

large saving, in operating expenses over the manual.

Different installations figured will have some variation in the relative amounts, but if will be found as a common result that first costs and fixed charges are higher for the automatic system, and that the total yearly charge is substantially less. It is thus found to be a good business proposition to install the more expensive equipment.

VII. BATTERY SUPPLY AND SUPERVISION.

The current for operating the calling devices may be supplied to the private branch exchange by three different methods: by storage batteries at the private branch exchange charged over cable pairs from the central office, and by current supplied directly from the central office battery over one or more cable pairs.

When direct current of 110 volts or 220 volts is available at the private branch exchange the battery may be charged locally by connecting it to the source of supply in series with a resistance. The charging current can be adjusted at such a rate as to keep the batteries in a condition of fairly constant voltage and specific gravity when taken over a long period, and be allowed to charge at this rate all the time. Protective devices are necessary so that in case of interruption of the supply, it will not be possible for the battery to discharge locally through other current consuming devices on the same supply circuit.

If alternating current must be used, a rectifier or motor generator set is installed, and the batteries are commonly charged at a relatively high rate for certain definite periods, rather than continuously at a low rate.

Charging over cable pairs from the central office usually is more satisfactory for private branch exchange which cannot receive attention at regular intervals. The charging current is usually maintained at a certain value throughout the twenty four hours, depending on the heavy calling of the day to discharge the battery somewhat, and on the charging current through the times

of light calling to bring it back to its normal condition. Occasionally different current rates are maintained through different periods of the day. A record of the battery performance is kept, consisting of periodical readings of battery voltage and occasional readings of specific gravity. If the voltage becomes abnormally low the charging current may be considerably increased temporarily and then the regular charging current increased slightly if necessary.

Supplying current without storage calls over cable pairs from the office is a common method for manual private branch exchanges, but is not generally favored in automatic work because quite heavy currents may be needed temporarily. Several switches operating at once may require as high as five or six amperes for a second or two. When cable pairs are depended on to furnish this current the drop of voltage due to the excessive current over a line of comparatively high resistance may be so great as to lower the voltage at the private branch exchange end below the lowest value at which the switches will operate accurately, usually about 46 volts. A large number of pairs in parallel or special conductors would be required to avoid this drop. It is better to charge a battery at a low rate and depend on it to provide for large current demands which it will do and still maintain its voltage.

When the method of battery supply cable pairs is used as it is on manual boards an interesting feature is observed. The pairs carrying the battery current are connected to bus bars at the private branch exchange. From these bus bars the talking circuits are taken off separately through impedance coils, or retardations

coils, as they are called. It is found that, in addition, a condenser of large capacity must be connected directly across the bus bars or there will be trouble from cross talk in the trunk cable originating in the battery carrying pair. An explanation of this phenomenon will be attempted.

In the first place when final connection is established between two lines there is a direct current flowing around the complete circuit of a value dependent on its total resistance. When a person speaks into one transmitter, his voice sets up an alternating voice current in the line in addition to and superposed on the direct current already flowing. Now when several of these talking circuits are supplied from the same battery the disturbance of the alternating current will cause cross talk in the other lines from induced currents. By introducing iron cored coils of high reactance, into both sides of each talking circuit it is found that the cross talk between talking circuits is practically eliminated. The impedance coils offer no hinderance to the passage of the direct current in the lines beyond a small resistance effect, but do choke down or retard the alternating part of the current so that its effect is minimized while passing through the battery. When a long cable pair still intervenes between the impedance coils and the battery at the central office there will be a certain amount of the alternating voice currents which will pass the impedance coils, and the effect of these currents produces cross talk in the trunk cable. The action of a condenser is to present an absolute check to the

flow of direct current but to allow alternating current to flow freely. When placed across the bus bars of the private branch exchange the condenser has no effect on the direct current, but presents an almost perfect short circuit path for the alternating voice currents. The alternating currents pass through the impedance coils which prevent one talking circuit from producing cross talk on another, and then pass on through the condenser. The alternating currents thus do not traverse the battery pairs in the trunk cable so there are no corresponding cross talk troubles.

Automatic equipment is naturally in groups of parts and it is customary to have the battery supply brought to these groups by separate circuits from the bus bars. Each circuit is fused and an alarm circuit is interconnected with the fuse so that when the fuse flows the alarm is given. This alarm may be local where there is an electrician or engineer in charge, or it may call the attention of the wire chief in the central office. The flowing of a single fuse seldom withdraws battery from any great amount of apparatus. The wire chief can sometimes by removing the battery supply from the board release a stuck switch, and in that way clear the main trouble while still leaving the fuse to be replaced at the first opportunity.

The methods of testing lines in outlying unattended stations such as the private branch exchanges, have been greatly improved. The board may be provided with what is known as a test connector. The test connector has its circuits so arranged that it will make connection even with a busy line. In addition to the regular

calling and talking circuit of the connector, the test connector carries on additional pair of wipers with a pair of wires absolutely free from magnets and other resistances. By means of this extra pair of wires the wire chief is able by calling the line and using a voltmeter, to test the line for accidental grounds, short circuits, and other trouble likely to occur. This is done from his desk at the office with ease and dispatch. He is able at all times to ascertain the exact condition of any suspected line and take the necessary steps for its repair.

VIII. CONCLUSION

In this discussion of private branch telephone exchanges the writer has tried to show that the use of such exchanges promotes both convenience and economy, and is therefore a desirable step in telephone development. It was pointed out that where a number of telephones are installed in a given establishment, or are likely to be needed ultimately, the private branch exchange presents advantages over the other methods available for providing these establishments with telephone service. The local lines used are short and inexpensive to install, and are easily changed to relocate a telephone. The minimum number of trunks to the city exchange is provided, and useless investment in idle cable avoided.

The rental per telephone is considerably less than for direct lines to the exchange, and as a result the owner of the establishment is likely to distribute a larger number of instruments through the establishment, thus making it convenient to use the telephones and lessening the time required to communicate from one part to another.

The two kinds of private branch exchanges were discussed somewhat in detail, attention being called to their characteristics and special features of operation. Extensive use of manual systems before the automatic telephone was invented developed a preference for that type among telephone engineers.

They have extended this preference to include private branch exchanges, and the automatic systems have had it to combat.

The chief argument in favor of the manual system has been

that the use of an operator provides human intelligence to insure accuracy, speed and other qualities necessary for good service. The objection to the automatic system has been that it seemed costly, complicated and easy to get out of order. Further claim has been made that subscribers object to the extra duty imposed on them of operating the dial in numbers.

In regard to the latter claim, inquiry in a number of cases seems to show that users of telephones; especially private branch telephones, are so accustomed to handling various devices that they prefer to call their number rather than to wait while the operator calls. By so doing they are occupied until the call is completed. They are then able to make an estimate of the time it may require to receive an answer and hence do not become impatient.

While the regular telephone operator possesses the intelligence necessary to do rapid and accurate work she is largely prevented from exercising the quality to any considerable extent. Exchange operators are trained to work as nearly like a machine as it is possible to do. For private branch exchanges, it was pointed out that the use of an operator makes service slow, but that by doing special favors which would necessarily make her neglect regular calls and thus delay service still further, the operator might, from some viewpoints partially offset this difficulty.

The consideration of the automatic system seems to indicate that it is able to do everything that is desired on a manual board,

and still avoid most of its bad features. The calls are made rapidly, accurately, and in a uniform manner, and do not require an appreciably longer time when entering or leaving a private branch exchange. In case special service is wanted it is rendered by some person who is not thereby forced to neglect other calls.

The mechanical construction of the automatic apparatus is so excellent that while complicated the various mechanisms do not get out of order easily. The cost comparison previously made shows that while the equipment is costly there is a large annual saving in operating expenses.

In conclusion it may be stated that the common preferences for the manual and the strong objections to the automatic system do not seem justified either on grounds of excellence of service rendered, or of considerations of relative economy. The automatic system seems to be applicable to practically every form of private branch exchange service, and to give rapid, accurate, and satisfactory results, with a minimum of delays and at a minimum expense. In view of these considerations it is probable that the automatic private branch exchange will have a much wider application in telephone practice in the future than in the past.


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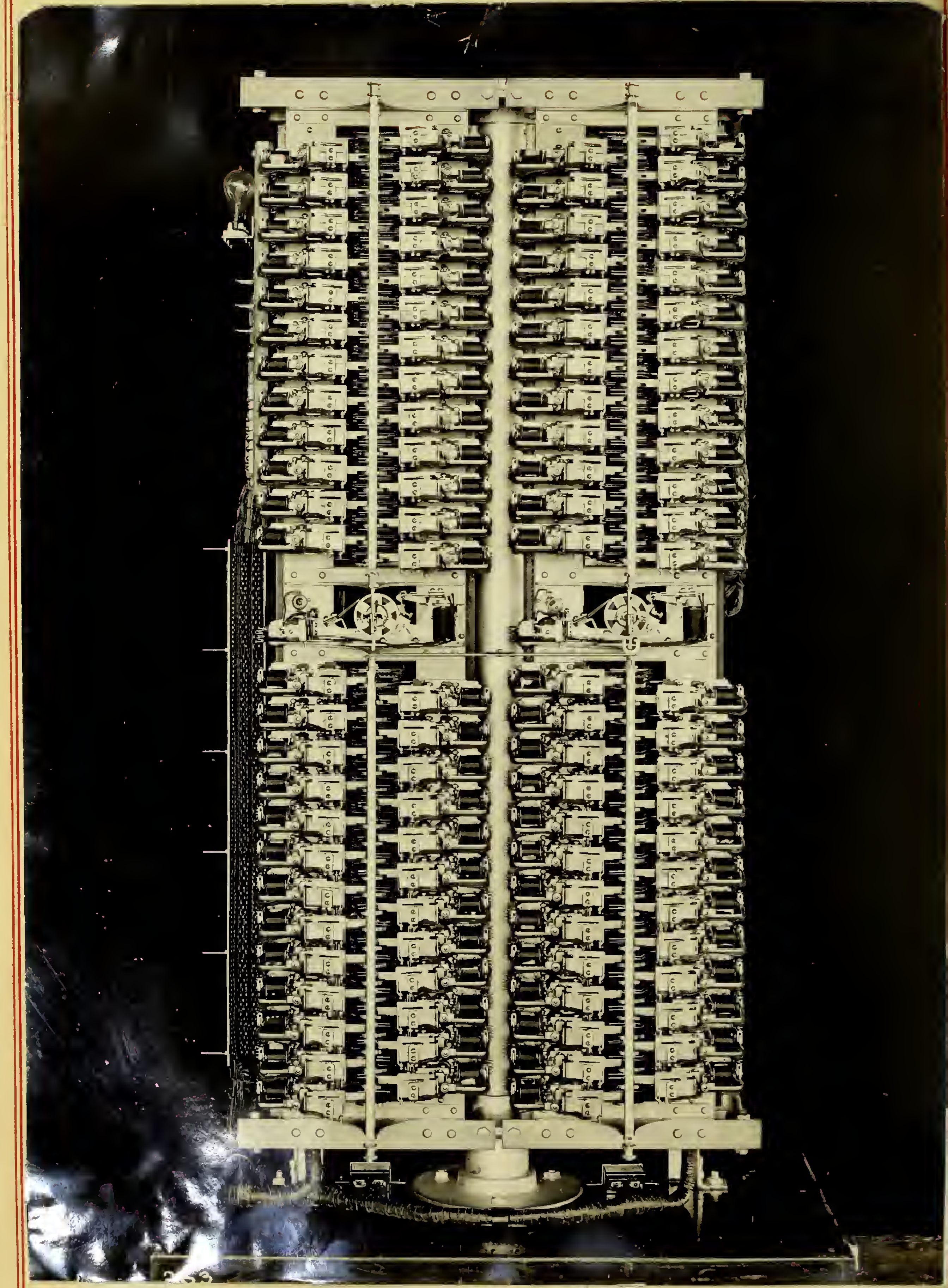
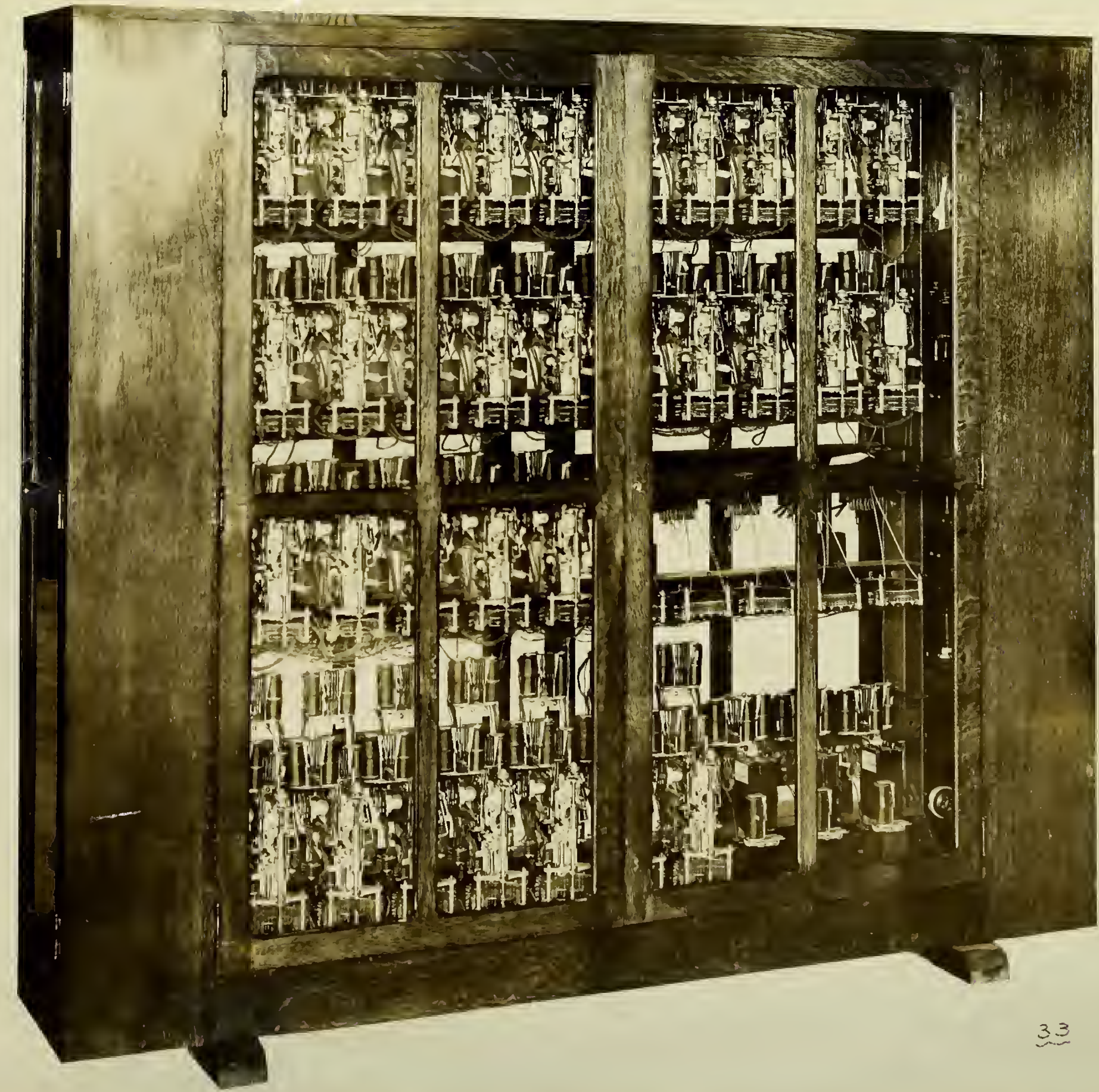


Keith type line switch board of one hundred lines capacity, showing arrangement of individual line switches. The group arrangement may also be noted which enables the twenty-five and fifty line boards to be arranged.

One type of Keith line switch showing plunger and electro magnets. Two views of the bank are shown indicating the arrangement of the trunk contacts.



Selector type of Private Branch Exchange board showing two level selectors and three level connectors on bottom row.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